Chapter 4

Measuring Flow and Consumption

To manage water it is essential to measure it. The primary uses of meters are to measure flow rates and consumption. Dataloggers capture the information and communicate this electronically. This chapter is devoted to a brief discussion of meters and dataloggers.

4.1 Flow Measurement

The ability to measure flow is critical to a water conservation programme. Selecting the right flowmeter for the task at hand will ensure that the results are accurate and repeatable. It will also provide value for money by minimising purchasing, installation and maintenance costs.

There are many technologies for measuring flow in closed conduits. This number is rising yearly. The advent of microelectronics in flowmeters has significantly improved their accuracy, ease of use and maintenance.

However, a highly accurate water meter is not required for all occasions. The best method of measurement is dependent on a number of factors:

- How accurate should the flow measurement be?
- Can the measurement be done manually? For instance, a flow cup such as in Figure 4.1 may suffice when measuring flow from taps. Or even a calibrated container and a stop watch could be used for measuring showers and basins.
- When were the meters calibrated? How old are the meters? Generally a turbine-type meter has a life expectancy of 10 years
- What is the expected flow to be measured? High velocities can wreck some types of meters.
- Are there any existing meters on-site that can be connected to a datalogger to be read remotely?

Figure 4.1 A photo of a flow cup

Courtesy of Con-Serv Pty Ltd.

- Are the readings required over a period of time such as 4–6 weeks or will a one-off measurement suffice?
- What is the pressure and temperature within the pipes?
- Are intrinsically safe meters and dataloggers required such as in oil refineries?
- Is the water ultra pure? Ultrasonic flowmeters are not suitable for such conditions. In dirty water systems mechanical meters may get blocked
- Is the meter easily accessible? Meters need to be accessible to be read and calibrated.

For measurement of water flows from taps the flow cup shown in Figure 4.1 will suffice. It is inexpensive, easy to use and the accuracy is generally acceptable. To measure water flow using a flow cup, simply place the cup under the tap, turn flow cup mechanism until the water does not overflow. At this point read the graduation on the side of the cup which can be read in litres per minute.

For water audits in commercial and industrial facilities to detect leaks and compute water balancing, it is essential to monitor the main water meter/s and install sub-meters in the main water-using areas. A brief description of the common water-meter types and their characteristics are given below.

In selecting a flowmeter, the desirable characteristics are the following:

- Measure flow with high accuracy over a wide range of operating conditions (e.g. low flow and high flow).
- Offer easy installation in any section of the piping without having to shut down the system.
- Be rugged so as to function reliably for many years without scheduled maintenance.

- Generate little or no pressure drop.
- Reasonable initial cost with low maintenance and operating costs.

Below a brief description of flowmeters suitable for water-flow measurement is given.

4.2 Types of FlowMeters

Meters can be classified into five general categories, based on the way they work. These are shown in Table 4.1

The focus of this chapter will be on positive displacement and velocity meters which are described below.

4.2.1 Positive Displacement Meters (volumetric)

Positive displacement also known as volumetric refers to the movement of the meter's flow-sensing element which displaces a specific volume for each cycle. Positive displacement meters include the following types: volumetric,

Table 4.1 Classification of meters

Type of meter	Mode of measurement	Examples
Positive displacement	A known volume of water is physically displaced by the measuring mechanism.	Volumetric. Generally for small-diameter pipes between 15 and 50 mm pipe diameter (5/8–2 in.)
Velocity	Use the rate of flow to measure volume. They convert velocity measurements to flow measurements.	Propeller, turbine, ultrasonic, electromagnetic and differential pressure.
Compound	Used to measure large variations in flow by having large meter and a small meter in the same unit.	A turbine meter on the main line and a small meter on a bypass line, with a valve to direct water to one or the other meter automatically. Generally installed when the meter size exceeds 100 mm in diameter (4 in.).
Proportional	A bypass meter measure only a small proportion of the total flow. A multiplier in the meter then multiplies and records the total flow through the whole unit.	Used in water towers and fire lines. Relatively accurate for large flows. Not suitable for low flows.
Open-channel	Used for flow measurement in open channels.	Weirs, flumes are two types used. Usually used for measuring wastewater flows.

Figure 4.2 V100 Piston-type volumetric meter

Courtesy of Elster Metering Pty Ltd.

nutating disk, oval gear, rotating vane, oscillating piston and reciprocating piston. The flow rate is calculated based on the number of times these compartments are filled and emptied and multiplying it by a constant established for volume per cycle. Positive displacement meters are well adapted to applications requiring high accuracy, low flow rates over widely divergent flow rates with relative low pressure head loss through the meter. These are available for pipe diameters 15 mm (5/8 in.) to 50 mm (2 in.). Figure 4.2 shows a popular volumetric meter.

Piston meters have a piston that rotates within a volumetric outer chamber as water flows through the meter. As the piston completes each revolution a known volume of water is displaced. By coupling the inner piston to a counter via transmission system to a register through a magnetic drive and gear assembly, the total volume of water can be recorded or transmitted through a probe to a datalogger. The nutating disk is another example of a positive displacement meter.

Positive displacement meters cannot be calibrated. Any undue clearances (due to wear and tear or from impure water sources) between the rotating elements and the outer chamber in which it rotates allow water to pass through without being registered.

4.2.2 Velocity Meters

Velocity meters operate on the principle that water passing through a known cross-sectional area with a measured velocity can be equated into a volume of flow as per equation (4.1). Velocity meters are suitable for high-flow applications.

$$Q = V \times A \tag{4.1}$$

where

Q liquid flow through the pipe
V average velocity of the flow
A cross-sectional area of the pipe.

Velocity meters consist of

mechanical meters – turbine, propeller and multi-jet and,
non-mechanical – ultrasonic, electromagnetic and differential pressure types such as orifice meters.

Each type has its advantages and disadvantages when used in different operating conditions. For potable water applications generally mechanical meters are suitable. They are relatively inexpensive to purchase and install but require more maintenance since the moving parts are affected by abrasive substances. Non-mechanical meters are suitable for non-potable water which contains debris, require less maintenance but are more expensive.

4.2.2.1 Mechanical Meters

Turbine meters – A common type of mechanical meter is the turbine meter (Figure 4.3). Turbine meter operates by a turbine suspended axially to the direction of flow in a pipe. As the water passes through the pipe the turbine spins at a rate proportional to velocity of water flow. The blades rotation is detected by non-contacting sensor, and the volumetric flow rate is inferred from this measurement. The flow coefficient is calibrated in the laboratory and expressed in number of pulses/unit of volume. Applicability is in clean water systems. The meter is normally mounted with flanges to the existing pipe work. The output from the meter can be via a pulse from a reed switch

Figure 4.3 A photo of a turbine meter

Courtesy of Elster Metering Pty Ltd.

sensor and/or conventional mechanical counter or register. Other types are propeller or paddle wheel meters. These are similar to turbine meters.

4.2.2.2 Non-Mechanical Meters

Electromagnetic – Electromagnetic meters require a conducting fluid such as water to measure flow rate. When a conductor moves across a magnetic field, a voltage is induced in the conductor, and the magnitude of the voltage is directly proportional to the velocity of the flowing water, which as per Equation (4.1) is proportional to the flow rate.

The magnetic flowmeter is a true volumetric device unaffected by fluid properties. The flowmeter is free of obstructions and therefore creates negligible pressure loss. The conductivity of water needs to be greater than 1 μS/cm. Magnetic flowmeters are popular in the water treatment, mining, pulp-and-paper and food-processing industries. Their accuracy is 0.2–1% and they can be installed in 2.5–2500 mm diameter pipes. The output can be analogue flow rates (L/min) and/or consumption similar to the register of a conventional mechanical meter.

Ultrasonic meters – There are two types of meters – transit-time method and Doppler method. The transit-time type calculates velocity based on the time difference for an impulse to pass between two sensors (transducers) located on opposite sides outside of the pipe. When a sound wave is transmitted between the transducers in the direction of flow, its velocity increases over that in still water. Similarly, its velocity decreases when transmitted against the flow. The water velocity is calculated as a function of the difference between the upstream and the downstream transmission times, the angle between the wave path and the water flow, and the speed of sound in quiescent water (which is a function of the density of water).

The Doppler-type meters measure the frequency of sound signals that are sent through the water flow from a transducer head. The signals are reflected back to the transducer head from moving particles and air bubbles in the water. Based on the assumption that the suspended particles are travelling at the same velocity as the water stream, the water velocity becomes a function of the reflected sound waves in accordance with the Doppler principle.

Transit time meters are used on clean liquids, while Doppler-type meters are generally used on slurries or liquids with entrained gas. Ultrasonic meters have a typical accuracy between 1 and 5% of flow rate. Their attraction is lack of moving parts, fast response; essentially zero head loss, and bidirectional measurement capability. The velocity of sound in water varies by about 0.2% for every 1°C change in temperature, so measurement must be compensated to minimise errors. Figure 4.4 shows an ultrasonic flowmeter.

Ultrasonic transit time meters (Figure 4.4) are also available as portable hand-held instruments with clamp-on transducers suitable for short-term investigative work where critical applications cannot be shut down to allow an in-line meter to be cut in. These can provide velocity, volumetric and totalled flow with built-in datalogger and rechargeable battery.

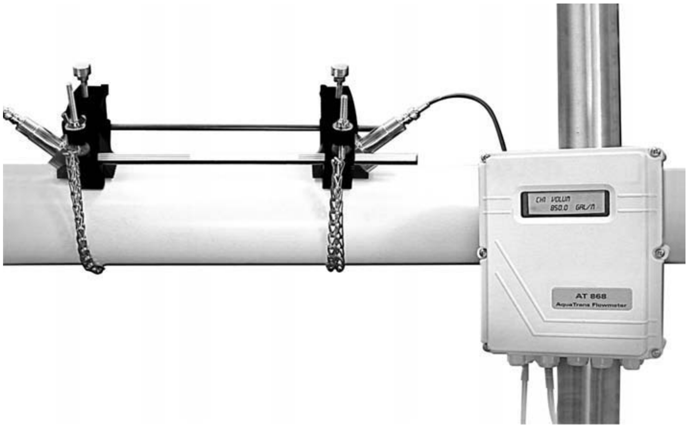

Figure 4.4 A photo of an Ultrasonic meter

Courtesy of GE Panametrics.

Other types of non-mechanical flowmeter types are orifice meters, rotameters, venturi tubes, pitot tubes and vortex shedding. Table 4.2 summarises the characteristics of flowmeters.

Table 4.2 Summary of velocity type flowmeters

	Most suitable application	Typical Accuracy	Pressure loss	Relative cost	Minimum straight run length of piping required upstream of meter in diameters
Mechanical (Turbine)	Clean liquid	0.1–1.0%	High	Medium	10–20
Magnetic	All types of liquids	0.2–1%	Low	High	5
Ultrasonic – Transit time	Clean and corrosive liquids. Some proprietary meters are capable of being used in dirty water such as raw sewage	2–5%	Low	Medium/ high	5–20
Ultrasonic – Doppler	Dirty liquids, corrosives and slurries	1–5%	Low	Medium/ high	5–20
Rotameter	Clean liquids	0.5–5%	Medium	Low	None
Orifice plate	Clean liquid	0.75%	High	Low	10–30
Vortex shedding	Clean liquid	1%	Medium	Medium	15–25

4.3 Selecting a Flowmeter

Given the range of meters, the questions to be asked when selecting a meter in no particular order of priority are

- What is the budget?
- Is it a permanent installation?
- Is the water clean or dirty?
- What is the pipe diameter?
- What is the desired accuracy?
- Will the flow rate be constant?
- What rangeability of measurement is required?
- Do pressure-loss limitations exist?
- Is an output signal required?
- Is it to be installed in an intrinsically safe environment?
- What is more critical: accuracy or repeatability?
- How much straight piping is available upstream or downstream of the flowmeter?
- Is excessive vibration likely to occur in the pipeline?
- Is the flow steady or pulsating?
- Will the pipe be constantly filled with water?
- What will be the orientation of the water meter be – horizontal or vertical?
- Is power available to the site or requires battery or solar power?
- Can the process be shut down to install the flowmeter?

4.4 Dataloggers

Most water meters provide only cumulative consumption readings and/or instantaneous flow rates. They do not provide time of use (TOU) consumption histories needed for the forensic analysis of system problems. To obtain such valuable TOU information, digital dataloggers are essential.

Dataloggers are low power devices typically powered by a long-life internal battery or external power sources such as solar panels. Dataloggers can be of the static or dynamic type. Static dataloggers need to have the data manually downloaded either in the field or on return to base. Dynamic loggers on the other hand have an inbuilt communications system that allows data to be automatically transmitted back to base. Static dataloggers are inexpensive and simple to use suitable for on-off logging.

Figure 4.5 shows a portable light-weight datalogger that can provide an output to a laptop computer. A solar-powered datalogger suitable for a remote site is shown in Figure 4.6.

Dataloggers have an inbuilt clock and microprocessor to time-stamp meter pulses counted over a user-definable interval (e.g. 5 minutes) and record data over long periods (e.g. 2–3 months but depending on the sampling rate).

Figure 4.5 A portable highly versatile datalogger

Courtesy of Hastings Dataloggers Pty Ltd.

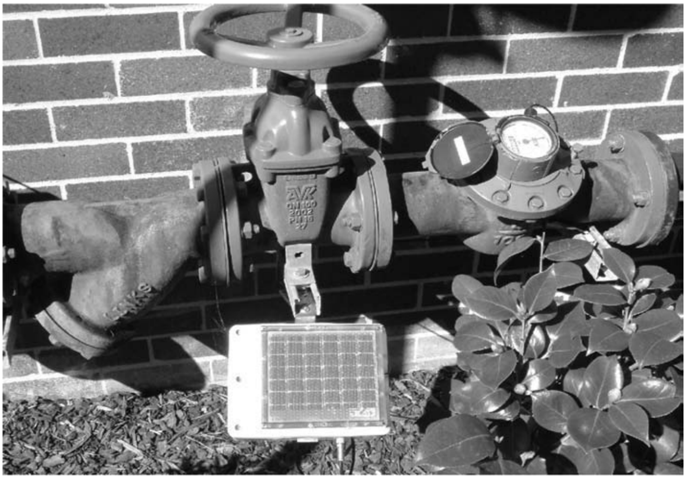

Figure 4.6 Photo of a solar-powered datalogger

Courtesy of National Project Consultants Pty Ltd.

Dynamic loggers are best for long-term permanent monitoring and automatic meter reading. Transmission to base is through a telemetry system linked to a central data system or to a host website. Transmissions between dataloggers and computers can be automatically error-checked to ensure accuracy of data transfer.

The common telemetry systems are

- Public switched telephone network – The datalogger is connected to a modem and linked to the public telephone network. Retrieval is via a telephone and receiving modem. Low set-up costs and ongoing costs are limited to call costs. Whilst reliable they require good access to a landline.

- Radio networks – Radio networks offer the advantage that they can be used in locations without landline telephone networks. The types of radio networks used are spread spectrum and single channel.
- Mobile telephone networks – These are based on GSM (Global System for Mobile communications) common in urban areas. The data is transmitted using packet switches commonly known as GPRS (General Packet Radio Service). Portable and reliable but can be expensive to operate. Code Division Multiple Access commonly known as CDMA has a greater coverage and higher data transfer rates compared to GSM because they use multiple channels transmitted over multiple frequencies. They also have ongoing call costs and high power consumption.
- Satellite Telephone networks – These do not have the limitations of CDMA and GSM technologies and have better coverage. However, they suffer from higher initial and operating costs.

4.5 Chemical Methods of Flow Measurement

Under certain circumstances chemical concentration methods can be used to estimate the flow through pipes or open channels. This method is based on injecting a known amount of a readily soluble salt such as NaCl and then measuring the conductivity and time taken to reach a known distance. Fluorescent dyes can be used instead of NaCl in non-potable waters that are not highly coloured. Some water-treatment companies also market proprietary systems under various trade names.

4.6 Conclusion

In conclusion, without measurement there cannot be control. The meters need to be selected with due consideration given for type of use, cleanliness of the water, budget and degree of accuracy required. Dataloggers will enable the user to monitor the data on a continuous basis. For high water users it is essential to have permanent monitoring systems.